<u>327 IAC 2-1-4(b)(5) - The measured or anticipated effect of the discharge on the quality of the receiving body of water</u>

There are no deleterious effects, measured or anticipated, on the quality of the receiving water body from implementing a mixing zone for the Amoco discharge. This is confirmed by the bioassessment field studies conducted by Amoco April to June 1994. A summary data report of these field studies, including methodologies and results, is presented in Attachment 5. Use of the proposed diffuser would reduce the magnitude and duration of exposure of organisms to constituents of Amoco's effluent, thereby providing an added protective benefit to the receiving water environment. A summary of the Amoco bioassessment program is given below.

<u>Bioassessment Study Design</u>. The objective of the field bioassessment was to determine if there are differences in community structure and function of aquatic communities inside and outside the immediate area of the discharge. The characteristics of these differences were used to evaluate the possible effects from the Amoco discharge or natural conditions. To maximize the opportunity to detect differences in community structure and function, the bioassessment was conducted during the spring and early summer months. It is during the spring and early summer that Lake Michigan typically exhibits greater biological activity, such as maximum plankton standing crop, because of increasing temperatures and nutrient availability from normal annual physical dynamics of the lake system. Common community structure descriptive parameters such as species richness and taxonomic similarity, diversity, density and estimations of productivity were used to assess community differences.

The USEPA has recognized that in order to compare the difference in biological communities potentially impacted by a discharge to a lake, the reference area should be located beyond the mixing zone. The areas studied were those defined by the hydraulic boundaries established for Outfall 001 through the August 1991 dye tracer study, August 1991 and April-June 1994 field measurements of non-degradable constituents, and general field observations. Study stations were located within the area defined by the effluent dispersion zone as well as outside of this area. The effluent dispersion zone extends to the point where ambient receiving water concentrations were measured. The reference or background areas were located beyond the effluent dispersion zone.

The USEPA recommends evaluation of the benthic community to assess potential impacts from mixing zones because the benthic community is sessile and likely to receive maximum exposure (EPA TSD and WQSH). Due to the natural physical characteristics of the southern end of Lake Michigan in the immediate area of Amoco's discharge (dynamic system with sand substrate), the benthic community is not well established or abundant. Therefore, the planktonic community, which is typically distributed by the same hydrodynamic forces that determine mixing patterns, was also selected for study. The drifting plankton community is a good candidate for evaluation because as a primary producer and consumer, it is integral to the overall health of the lake ecosystem. A graphic representation of the study design concepts with respect to anticipated exposure-based sensitivity to discharged waters is presented in Figure 4-1.

To determine the impact of the varying ratios/mixtures of effluent and Lake Michigan water, community structure characteristics of the aquatic communities collected from the study stations were analyzed. Personnel from the ADVENT Group Inc., (ADVENT), and Advanced Aquatic Technology Associates, Inc. (AATA) visited the Amoco Cove site to establish sampling locations and collect a series of biological samples. Sites were established as S120, S340, S650, S1000 within the Amoco Cove, and S2000 and S3500 in the near-shore region adjacent to the Amoco Cove (the station number corresponds to the distance (in feet) from Outfall 001. Biological samples were collected during the week of April 22 in the Amoco Cove for benthos and net plankton. Samples were collected for phytoplankton (composite grab samples), periphyton at all Amoco Cove stations, and benthos at S2000 and S3500 during the week of May 10. Water chemistry samples, *in situ* water quality measurements, chlorophyll-a samples, and particle size distributions were collected for all stations during the above listed sampling periods. Shore periphyton (filamentous macro-algae) samples were collected from rock rip-rap substrates near Outfall 001 and a separate local southern Lake Michigan cove during the week of May 31. Standard USEPA collection techniques, enumeration and analytical procedures, metrics development and statistical comparisons were incorporated into the study design.

The functional aspects of a typical community exposed to different effluent and receiving water ratios were investigated by conducting an algal bioassay test. Phytoplankton exposed to mixed effluent conditions from within the effluent dispersion zone, outside the dispersion zone, and at the proposed diffuser site were used as test conditions. Conditions within the effluent dispersion zone were mimicked by combining raw Outfall 001 discharge water with filtered Lake Michigan water collected from the proposed diffuser site. Water samples for the algal bioassay test were collected the week of July 25, 1994. Based on previous dispersion modelling and dye studies, test conditions at site S120 were replicated by a 20:1 Lake Michigan water to effluent ratio, and conditions as S340 were replicated by a 40:1 Lake Michigan water to effluent ratio. Water samples collected *in situ* from S120 and S340 (representing the effluent dispersion zone) and water from S3500 (representing outside the dispersion zone) were also used as bioassay test conditions. The bioassay procedure followed the *Selenastrum capricornutum* Printz Algal Assay Bottle Test (EPA 1978) protocols to determine presence of stimulatory or toxic effects on two species of green algae. *Selenastrum capricornutum* and *Scenedesmus quadricauda* were selected as test species to generate test results using cell counts, chlorophyll-a and dry weight biomass data.

The unique nature of the Amoco Cove is recognized as a beach water zone which has extremely turbulent, unstable and highly fluctuating physical and chemical conditions. It follows that under such environmental variability there is normal biological variability. The biological assessment served as an evaluation of a very dynamic environment with highly variable physical, chemical, and biological constituents. Commonly used community structure parameters such as taxonomic richness, measures of diversity, organism density, and taxonomic similarity were the focus for biological comparisons.

Bioassessment Results. Analysis of the biological samples included taxonomic identification and enumeration of the benthos, phytoplankton, zooplankton and periphyton communities collected at each sample site. Descriptive community structure metrics for each community type were used to assess potential differences between biological communities collected from sites located within the current dispersion zone and biological communities collected outside the boundaries of the dispersion zone. Analysis of Variance (ANOVA) statistical procedures were used to test for significant differences in community structure.

Analysis of the biological samples and statistical results showed few differences were present between biological communities within the effluent dispersion zone and biological communities located outside the dispersion zone (Table 4-2). Important findings are presented below.

1) The harsh physico-chemical environment of the flooded beach zone is very unstable and unsupportive of extensive or fully developed complex aquatic communities commonly observed in deeper, off shore waters. Low richness and diversity values were observed in the biological collections from the effluent dispersion zone area (sites S120 and S340) and outside the dispersion zone (sites S650, S1000, S2000, and S3500). Visual observation during sample collection indicated extensive disruption and unstable physico-chemical ecological conditions resulting from the turbulence and natural physical setting. The flooded beach zone is characterized by a nearly constant fluctuation in physico-chemical properties directly related to the shallow waters along the Lake Michigan shore.

2) As anticipated for the Amoco cove, aquatic communities associated with substrates in the study area were sparsely represented in the sample collections. The benthic community was not well established in the shifting sandy substrates and exhibited low richness values at all stations. Although members of the Oligochaeta, Amphipoda, Diptera and Molluska were represented, zero benthic invertebrate organisms were observed in some replicates within the dispersion zone, and only a total of 7 different benthic invertebrate taxa were identified from all locations. The benthic periphyton community was effectively absent at all sample locations because of a lack of stable, suitable substrate due to the natural turbulent sandy bottom. Analyses of the natural algal periphyton collected from the shifting sand substrates (epipsammon) indicated that true benthic algae are depauperate and not well established on the sandy substrates, but tangles of un-attached fragmented algae more characteristic of the splash zone and shore periphyton exist in the area.

3) Aquatic communities associated with the water column (plankton) exhibited a higher degree of community development than sessile communities. The phytoplankton represented members of all the major algal groups and typically exhibited the highest richness and diversity of all aquatic communities. A total of 60 different diatom taxa and 13 different non-diatom algal taxa were observed from the phytoplankton collections. The zooplankton community was less diverse than the phytoplankton community and was dominated by cyclopoid, calanoid, and harpacticoid copepods

(Crustacea). Over half the organisms observed were early life stages (nauplii) of copepod crustaceans. Analyses of the ichthyoplankton samples resulted in no larval fish present. Fish spawning is typically triggered by temperature changes in the water column and excessive cold or long winters can alter warming patterns. The lack of larval fish in the collections was most likely a result of the extremely cold 1993-1994 winter which delayed warming of the waters resulting in delayed spawning and premature sampling.

4) Statistical differences identified by ANOVA procedures on descriptive community structure parameters between sites within the effluent dispersion zone and sites outside the dispersion zone included the following:

- Significant differences in biological community structure parameters between samples collected inside the effluent dispersion zone and samples collected outside the dispersion zone were associated with communities that were extremely poorly developed because of natural physical and habitat limitations (benthos community), or communities that were artificially present during the sampling period and normally do not occur (float periphyton on site marker buoys), or communities that have very limited exposure to direct influence with discharge waters relative to other physico-chemical properties (matted filamentous shore periphyton).

- Mean benthos richness and mean benthos density were significantly higher in samples collected beyond the dispersion zone than samples collected from within the effluent dispersion zone. However, a statistical difference of only 1.2 taxa is ecologically and biologically negligible and illustrates the overall lack of benthic invertebrate community development due to the turbulent natural habitat and unstable conditions.

- A wide range in benthic invertebrate density was observed among the sites. Highest benthic organism density was observed at S2000 outside the dispersion zone and the least dense collections were at S120 within the dispersion zone. Low benthic organism density is likely confounded by increased turbulence from the discharge currents at the S120 and S340 sites. Therefore, the statistical difference in mean benthos density inside and outside the effluent dispersion zone is most likely an artifact of interactions with additional turbulence from the effluent discharge energy.

- A mean phytoplankton diatom richness of 34.7 taxa from within the effluent dispersion zone was significantly higher than a mean phytoplankton diatom richness of 27.8 taxa from outside the dispersion zone. A review of the taxa suggested the increased phytoplankton richness within the dispersion zone consists of algae typically associated with sediments or attached surfaces. The presence of this type of growth form in the plankton suggests a possible source of dislodged and resuspended periphyton (tychoplankton) from the shoreline. Migration of tychoplankton from the shoreline into the local open waters commonly occurs, and the observed significant difference in richness is likely an artifact of proximity to the shoreline. This assemblage of taxa implies that resuspension of dislodged attached algae, or tychoplankton, from the nearby shoreline contributes to the increase in taxonomic richness.

- Two taxa (*Nitzschia stagnorum* and *Nitzschia frustulum*) which were observed from only the effluent dispersion zone are reported by Lowe (1974) to be obligate nitrogen heterotrophs. However, low relative abundance of these taxa inside the dispersion zone, and the presence of other *Nitzschia* species that are considered eutrophic indicators (*Nitzschia palea*, *Nitzschia kutzingiana*) indicates that there are no nutrient effects from Outfall 001. Similarly, an affinity to highly saline or brackish waters was not attributed to any the phytoplankton diatom taxa which were identified from only the dispersion zone.

- Diversity, as estimated by Shannon-Weiner Diversity (H'), Simpson's Diversity (λ), and Hill's number of dominant taxa (N1), for the matted filamentous algae growth located at the waterline (shore periphyton) was higher in the vicinity of Outfall 001 (Amoco Cove) than for the matted filamentous algal growth from similar habitats located at Whihala Beach (reference shoreline west of Amoco facility). Differences in community structure were attributed to the more developed epiphyte (algae attached to macro-algae) community associated with the *Cladophora glomerata* (Chlorophyta) and *Ulothrix zonata* (Chlorophyta) algal complex characteristic of the Amoco Cove location, and the limited epiphyte community associated with the *Cladophora glomerata* and *Bangia atropurpurea* (Rhodophyta) complex found at Whihala Beach. *Bangia atropurpurea* is commonly known to not support other algal epiphytes (Lowe, et al. 1982).

Colonized periphyton collected from the sample site marker buoys (float periphyton) were shown to have a higher mean taxonomic richness outside the dispersion zone (mean = 24.6 taxa) than inside the dispersion zone (mean = 20.8 taxa). The presence of periphyton on the sample site marker buoys helps illustrate that when a stable substrate is available, algal colonization can occur. Little ecological significance to differences in richness without concurrent differences in density can be attributed to algal communities during the colonization period.

5) The algal bioassay results were subjected to statistical tests using ANOVA procedures and appropriate multiple range tests to identify significantly different exposure treatments. Cell counts of test species were recorded daily, and final (8 day) chlorophyll-a and dry weight data were compared to initial chlorophyll-a and dry weight conditions. No toxic effects were recorded for either *Selenastrum capricornutum* or *Scenedesmus quadricauda* in any of the test conditions. No treatment conditions stimulated algal growth different than observed for the 100 percent Lake Michigan (receiving water) test condition. No statistical differences were found for chlorophyll-a or dry weight among any of the artificial 20:1 and 40:1 receiving water and effluent ratio, and the *in situ* dispersion zone waters, and 100 percent Lake Michigan receiving water test conditions. A significant difference was observed for chlorophyll-a between the *in situ* 20:1 effluent ratio and the artificially mixed 20:1 effluent ratio for *Selenastrum*. However, no matching significant differences in dry weight were observed for this same treatment comparison.

A Data Summary Chart, Table 4-2, shows the statistical comparison (ANOVA) results on mean values for richness, diversity measures, and density estimated for each type of community sampled from inside the effluent dispersion zone and outside the dispersion zone. Shaded boxes signify ANOVA results that were statistically significantly different. A complete description of bioassessment results is given in Attachment 5.

Summary of Biological Observations. There are no measured adverse effects on aquatic life attributable to the chemical characteristics of Amoco's existing effluent dispersion zone.

The current discharge (Outfall 001) is from a shoreline location into water approximately 10 feet deep, versus the 28.5 foot depth of the proposed diffuser discharge to open water. The substrata of the two sites is very similar, comprised of shifting fine sand. Phytoplankton of the enclosed cove contains a higher percentage of "tychoplankton", (algae which are not open water forms, but, rather, are detached from benthic or shoreline habitats), than the proposed diffuser site. Some natural growth of algae associated with sand particles (epipsammon) was observed in the shallow cove. The benthic macroinvertebrate and epipsammon communities are largely limited by the unstable, shifting sand. Turbulence in the shallow cove during windy periods can be extreme, moving large amounts of sand back and forth across the bottom of the cove to a water depth of over 30 ft, and resuspending the sediment particles from the bottom throughout the water column.

The proposed diffuser would assure that there would be no anticipated effect of the effluent on the receiving water. As a matter of fact, the proposed diffuser site offers some ecological advantages over the shallow cove site for discharge. Rapid and immediate mixing will be enhanced due to the diffuser and water depth of the site. In addition, the zone of mixing will be a smaller area.

327 IAC 2-1-4(b)(6) - The existence of and impact upon any spawning or nursery areas of any indigenous aquatic species

The proposed diffuser site does not represent a spawning or nursery area for any indigenous aquatic species (fishes). The water depth is too deep to support spawning for common fish such as carp (*Cyprinus carpio*) and does not support appropriate, or any preferred, substrate type suitable for spawning centrarchids (sunfishes). Rock rip-rap or other fixed substrata does not exist at the proposed diffuser location which could be utilized for fish habitat. It is anticipated that the introduction of fixed substrate (diffuser equipment) will increase benthic habitat diversity, and the 90-ft diffuser header will likely be colonized by attached algae, mussels, and possibly other organisms. The anticipated benthic colonization will be minor, and there will be no impacts to any existing fish spawning or nursery areas.

327 IAC 2-1-4(b)(7) - Any obstruction of migratory routes of any indigenous aquatic species

The size of the mixing zone delineated from the proposed diffuser will be minimized to provide rapid and complete mixing within a small allocated impact area. Since the mixing zone will be located in an area unconfined by immediate shoreline or other structures, and does not contact any shoreline, no obstruction of any migratory routes of any indigenous aquatic species can occur. The 90-ft diffuser header will also not be an obstruction to any migratory routes of any indigenous aquatic species.

327 IAC 2-1-4(b)(8) - The synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones

No mixing zones from other local discharges are located within or adjacent to the proposed Amoco diffuser mixing zone. The Amoco mixing zone does not contact the Lake Michigan shoreline or encroach upon drinking water or industrial intakes.

OVERALL SUMMARY

The background information on Lake Michigan, the recent biological studies of the Amoco discharge site (including comparisons inside and outside the dispersion zone), and the application of state and federal mixing zone guidelines all demonstrate that regulatory implementation of a mixing zone is appropriate and will not cause harm to human health or aquatic life.

TABLE 4-1. COMPARISON OF OUTFALL 001 CHARACTERISTICS TO FEDERAL PRIMARY DRINKING WATER STANDARDS

CONSTITUENTS (a)		NPDES PERMIT APPLICATION CHARACTERIZATION DATA Maximum Daily Value	DRINKING WATER MAXIMUM CONTAMINANT LEVEL (b)
METALS			
Arsenic	µg/L	21	50
Barium	µg/L	90	2,000
Beryllium	µg/L	2	4
Chromium	µg/L	30	100
Copper	µg/L	29	1,300 (c)
Lead	µg/L	13	15 (c)
Nickel	µg/L	7	100
Selenium	µg/L	45	50
OTHER SUBSTANCES			
Cyanide (Total)	µg/L	1.9	200
Nitrate-N - Nitrite-N	mg/L	0.5/<1.0	10
Fluorides	mg/L	0.3	4

NOTES:
(a) Constituents presented have been detected in Amoco's treated effluent. Other constituents with federal primary drinking water standards were not detected in the effluent.
(b) EPA National Drinking Water Regulations in 40 CFR Part 141, except where noted.
(c) Action levels from 40 CFR 141 Subpart I.

TABLE 4-2

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Benthos				
Diversity Index-Shannon-Weiner	No		0.28	0.60
Diversity Index-Simpson's	No		0.60	0.67
Richness	Yes	No[a]	1.4	2.6
Density (organisms/M^2)	Yes	No[a]	122.1	1082.6
Evenness	No		1.00	0.84
Dominant Taxa Number-Hill's N1	No		1.4	1.8
Bray-Curtis PD Associations	No		1.00	0.52
Phytoplankton				
Diversity Index-Shannon-Weiner	No		2.11	2.06
Diversity Index-Simpson's	No		0.19	0.19
Richness	Yes	No[b]	34.7	27.8
Density (10^5 cells/L)	No		2.6	3.0
Evenness	No		0.62	0.62
Dominant Taxa Number-Hill's N1	No		8.4	8.0
Bray-Curtis PD Associations	No		0.22	0.34

1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

a Reductions in benthos richness and density in the dispersion zone are attributed to additional turbulence and disruptive forces at the sediment surfaces from the discharge energy, further limiting the establishment of an already sparse benthic community.

b A review of the taxa suggested the increased phytoplankton richness within the dispersion zone consists of algae typically associated with sediments or attached to surfaces. The presence of this type of growth form in the plankton suggests a possible source of dislodged and resuspended periphyton (tychoplankton) from the nearby shoreline. Migration of tychoplankton from the shoreline into the local open waters commonly occurs, and the observed significant difference in richness is likely an artifact of proximity to the shoreline.

TABLE 4-2

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Zooplankton				
Diversity Index-Shannon-Weiner	No		0.51	0.74
Diversity Index - Simpson's	No		0.79	0.62
Richness	No		11.2	12.5
Density (# organisms/L)	No		21.9	15.5
Evenness	No		0.37	0.57
Dominant Taxa Number-Hill's N1	No		1.7	2.1
Bray-Curtis PD Associations	No		0.34	0.39
Float Periphyton				
Diversity Index-Shannon-Weiner	No		1.65	1.62
Diversity Index - Simpson's	No		0.18	0.17
Richness	Yes	No[c]	20.8	24.6
Density (10^5 cells/mm^2)	No		6.6	6.6
Evenness	No		1.41	1.20
Dominant Taxa Number-Hill's N1	No		5.3	5.2
Bray-Curtis PD Associations	No		0.14	0.31

1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

c The reduction of algal periphyton richness on the site marker buoys within the effluent dispersion zone is likely an artifact of the increased current forces in the water column from the discharge energy. A difference of only 3.7 taxa during algal colonization periods without a concurrent difference in algal cell density is not biologically meaningful. Natural substrate available for algal colonization in the water column do not exist in the Amoco Cove.

TABLE 4-2

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Shore Periphyton				
Diversity Index-Shannon-Weiner	Yes	Uncertain[d]	1.89	1.54
Diversity Index - Simpson's	Yes	Uncertain[d]	0.13	0.19
Richness	No		7.5	5.5
Evenness	No		1.30	1.21
Dominant Taxa Number-Hill's N1	Yes	Uncertain[d]	6.6	4.7
Bray-Curtis PD Associations	Yes	Uncertain[e]	0.27	0.29
Epipsammon Periphyton[2]				
Diversity Index-Shannon-Weiner	No		2.42	2.37
Diversity Index - Simpson's	No		0.11	0.10
Richness	No		16.5	16.0
Dominant Taxa Number-Hill's N1	No		11.2	10.8
Algal Bioassay Test				
Final Chlorophyll-a (μg/L) *Scenedesmus quadricauda* *Selenastrum capricornutum*	 No No		 13.8 1.6	 14.1 1.2
Final Dry Weight (mg/L) *Scenedesmus quadricauda* *Selenastrum capricornutum*	 No No		 34.4 1.7	 36.9 2.3

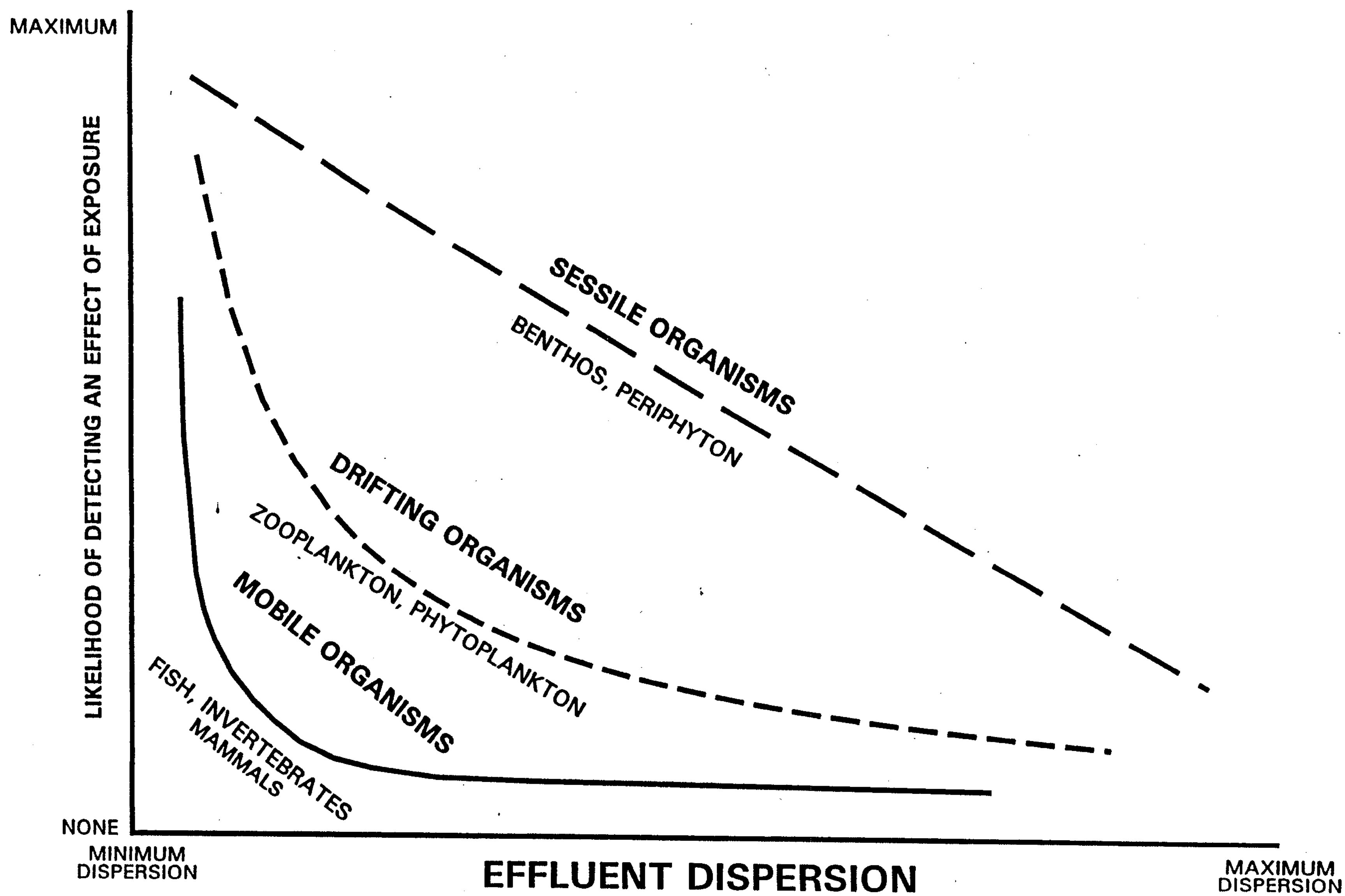
1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

2 Epipsammon periphyton based on 100 frustule counts.

d Differences in diversity measures between the shore periphyton collections are likely based on absence of *Bangia atropurpurea* at the Amoco Cove site. However, the observed differences in mean values for the diversity measures are biologically equivalent and should be considered negligible.

e Non-statistical evaluation based on mean PD values showing greater dissimilarity within each zone than between zones.

FIGURE 4-1. CONCEPTUAL COMMUNITY SENSITIVITY



3149UMX2DRAFT\FIG4-2.DRW

AUGUST 24, 1994

SECTION 5

MIXING ZONE DEMONSTRATION CONCLUSION

IC 13-1-3-20(a) states that "the commissioner shall allow for a mixing zone in permits that involve a discharge into Lake Michigan if the applicant can demonstrate that the mixing zone will not cause harm to human health or aquatic life". Amoco has submitted information in accordance with the Indiana Mixing Zone Guidelines presented in 327 IAC 2-1-4. The Indiana Mixing Zone Guidelines require similar information as federal regulation and guidance. Amoco's analysis of the Indiana Mixing Zone Guidelines, in combination with the Volume I information and the IDEM wasteload allocation process, establish that implementation of a mixing zone to define the point of application for receiving water quality criteria is environmentally protective of the designated use of the receiving water and will not cause harm to human health or aquatic life.

The receiving water, Lake Michigan, is designated for use as: a public, industrial, and agricultural water supply; full body contact recreation; support for a well-balanced aquatic community; and as an outstanding state resource water. The water quality criteria (numeric and whole effluent) presented in Article 2 are based on protecting the uses of the water. If the criteria are not exceeded in the receiving water, then the use of the water is not impaired and the designated use is maintained. As presented previously in Table 1-4, the quality of Lake Michigan, as measured and summarized by IDEM, does not exceed the water quality criteria for the listed substances. Therefore, the Indiana portion of Lake Michigan does have assimilative capacity for these Table 1-4 substances. The fact that assimilative capacity is available is a prerequisite for granting a mixing zone.

Another consideration, before proceeding with a mixing zone demonstration, is to confirm that the effluent quality is equivalent to that established by technology-based limits. That is, a mixing zone cannot be used to attain technology-based permit limits. As presented previously in Table 1-1, Amoco produces treated effluent that meets the existing technology-based limits. Effluent quality based on historical wastewater treatment plant performance is better than technology-based limits. Hence, Amoco is not using a mixing zone in place of wastewater treatment to achieve technology-based and existing permit limits. The mixing zone demonstration process for this effluent is appropriate.

Amoco has used every feasible approach to identify and evaluate possible adverse consequences from chemical impacts of its Outfall 001 effluent. Each approach has found that a "mixing zone will not cause harm to human health or aquatic life" (the criterion of IC 13-1-3-20(a)).

Amoco has shown that no adverse effects on aquatic life are attributable to chemical toxicity of its current discharge through both laboratory testing and a field study using standard ecological techniques. Based on standard USEPA methods and procedures, acute toxicity has not been measured or observed in Outfall 001 effluent. Amoco has studied the existing discharge (1991 Mixing Zone Delineation Study) and found that, within a 1,000 foot radius, the effluent is mixed thoroughly with Lake Michigan waters at a ratio of 50:1 to 100:1. Amoco has proposed installation of a new diffuser system that would achieve these results within a 500 foot radius. This proposed improvement would mean that mixing would occur within a much smaller area than the current area. The mixed effluent meets every applicable standard whether derived to protect human health (e.g., drinking water standards and Lake Michigan-specific standards) or aquatic life (e.g., water quality criteria).

Therefore, Amoco has demonstrated that a mixing zone for its Outfall 001 effluent is appropriate and meets the strict requirements of Indiana law and regulations, as well as the national guidance of the USEPA. The various approaches taken by Amoco, and the key findings, as detailed elsewhere in Volumes I and II, are briefly summarized below in this Section. The key findings of the Mixing Zone Demonstration are:

- Amoco is proposing to install a submerged multiport high rate diffuser in 30 feet of water approximately 3,500 feet from shore to assure rapid and immediate mixing in an area even smaller than where dispersion now occurs.
- According to the USEPA CORMIX2 model, a discharge-induced dispersion of 54:1 will be achieved within 50 feet of the diffuser and the total mixing zone of 500 feet will achieve a dispersion ratio of 77:1.
- This area of Lake Michigan is a flooded beach zone with natural constant turbulence and unstable sandy substrate. This is a harsh physical setting for most aquatic life. The field bioassessment studies confirmed this fact.
- This naturally turbulent and unstable setting limits benthic community development. This prevented using benthos to evaluate potential chemical effects of the effluent.

- A biological field assessment focused on the structure and function of the planktonic community inside and outside the current effluent dispersion zone. The sampling design maximized the power to detect any community impacts present.
- No significant differences attributable to the chemical characteristics of the effluent were found between aquatic communities living inside and outside the existing effluent dispersion zone.
- Operation of the proposed diffuser is anticipated to have no effect on these communities. In addition, the diffuser would further minimize the time that organisms would be exposed to the effluent.

Based on the findings presented in this report, a mixing zone can be used in Amoco's NPDES Permit renewal without causing harm to human health or aquatic life. This demonstration is consistent with Indiana law and rules, as well as USEPA guidance and procedures.

SECTION 6

RECOMMENDATION

As allowed by Indiana law, Amoco Oil Company, Whiting Refinery has provided the information necessary to demonstrate that implementation of a mixing zone in Lake Michigan for treated effluent, through use of a multiport diffuser, is protective of the environment. The mixing zone will not cause harm to human health or aquatic life. This conclusion is based on the water quality criteria designated to protect the use of Lake Michigan and the assessment of the local biological community. The engineering of the diffuser and resulting dispersion achieved make this conclusion overwhelmingly clear.

The biological community most susceptible with respect to effects of a mixing zone have been identified by the USEPA as the sessile organisms (e.g., benthic community). The benthic community has been found to be poorly developed in this area of the Lake due to natural dynamic physical characteristics (e.g., fine sands and turbulence). The portions of the biological community in this area that are likely susceptible to the effects of mixing zone are the drifting water column community e.g., plankton. In addition, plankton are good candidates for evaluation as they represent primary producers and primary consumers in this area of the Lake. Based on literature review and field studies, the abundance, diversity, composition, and function of these biological communities are typical for the habitat. Also there were no statistical differences between phytoplankton populations located inside the present effluent dispersion zone versus those populations located outside the dispersion zone. Therefore, with deeper water and an engineered structure inducing more immediate rapid mixing within a small area (thus providing an additional degree of safety to the receiving waters), the continued health of the benthic and planktonic community is expected.

Amoco requests that a mixing zone be established for a multiport diffuser in Lake Michigan that incorporates the conservative estimates modeled for S3500. The requested mixing zone delineation is summarized as follows:

- **Zone of Discharge Induced Mixing**

  Distance to edge of ZDIM = 50 ft

  Dispersion at edge of ZDIM = 54:1

- **Total Mixing Zone**

  Distance to edge of total mixing zone = 500 ft

  Dispersion at edge of total mixing zone = 77:1

The dispersion values conservatively derived from computer modeling and requested herein are appropriate for application to wasteload allocation procedures used to determine daily maximum and monthly average permit limits (as described in IDEM Technical Release OWM-1 "Procedure for Developing Water Quality-Based NPDES Permit Limitations for Toxic Pollutants"). The permit limits derivation procedures and results are given in Volume III of this NPDES Permit Renewal Application.

Based on the foregoing, Amoco's proposed mixing zone will not cause harm to human health or aquatic life.

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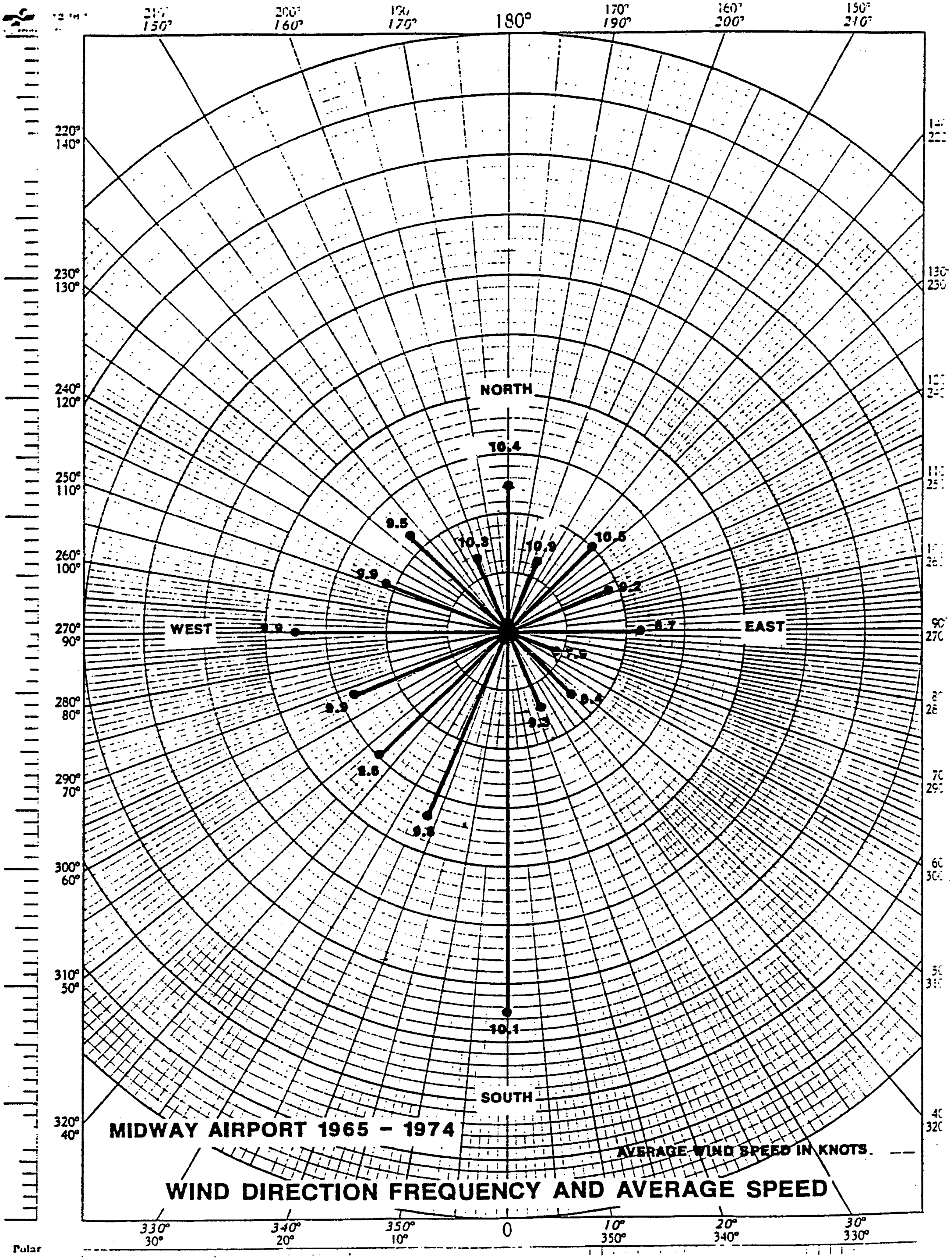
ATTACHMENT 1

WIND ROSE



MIDWAY AIRPORT 1965 – 1974

WIND DIRECTION FREQUENCY AND AVERAGE SPEED

ATTACHMENT 2

CORMIX MODEL OUTPUT

CORMIX2 PREDICTION FILE:

```
                         CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX2:                                                   Subsystem
version:
 Submerged   Multiport   Diffuser   Discharges
CMX2_v.2.10_____________May_1993
---------------------------------------------------------------------
---------------------------------------------------------------------

CASE DESCRIPTION
 Site name/label:          SITE^B
 Design case:              0.10mps
 FILE NAME:                cormix\sim\sitebv3 .cx2
 Time of Fortran run:      07/22/94--12:03:32

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA     =      8.69 HD     =       8.69
 UA     =      .100 F      =       .047 USTAR = .7647E-02
 UW     =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.7019

DIFFUSER DISCHARGE PARAMETERS (metric units)
 DITYPE=unidirectional_perpendicular
 BETYPE=unidirectional_without_fanning
 BANK  =  LEFT     DISTB =   1083.70  YB1    =   1070.00  YB2   = 1097.40
 LD    =     27.40 NOPEN =   10       SPAC   =      3.04
 D0    =      .152 A0    =       .018 H0     =       .50
 GAMMA =     90.00 THETA =        .00
 SIGMA =       .00 BETA  =     90.00
 U0    =     3.136 Q0    =       .569        = .5690E+00
 RHO0  =  995.6470 DRHO0 = .4055E+01  GP0    = .3978E-01
 C0    = .1000E+03 CUNITS=  PERCENT
 IPOLL =  1        KS    = .0000E+00  KD     = .0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    = .2077E-01  m0    = .6512E-01  j0    = .8260E-03  SIGNJ0  =  1.0
 Associated 2-d length scales (meters)
 lQ=B  =      .007 lM    =      7.38  lm     =      6.51
 lmp   =  99999.00 lbp   =  99999.00  la     =  99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    = .5690E+00  M0    = .1784E+01  J0     = .2263E-01
 Associated 3-d length scales (meters)
 LQ    =       .43  LM    =     10.26  Lm    =     13.36  Lb   =    22.63
                                       Lmp   = 99999.00 Lbp  = 99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =    193.18 FRD0  =     40.32  R      =     31.35
 (slot)            (port/nozzle)

FLOW CLASSIFICATION

 2  Flow class (CORMIX2)        =    MU2      2
 2  Applicable layer depth HS =       8.69   2
```

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+03 CUNITS= PERCENT
NTOX = 0
NSTD = 0
REGMZ = 0
XINT = 1000.00 XMAX = 1000.00

X-Y-Z COORDINATE SYSTEM:
ORIGIN is located at the bottom and the diffuser mid-point:
1083.70 m from the LEFT bank/shore.
X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 20 display intervals per module

BEGIN MOD201: DIFFUSER DISCHARGE MODULE

Profile definitions:
BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
BH = top-hat half-width, in horizontal plane normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
.00	.00	.50	1.0	.100E+03	.01	13.70

END OF MOD201: DIFFUSER DISCHARGE MODULE

BEGIN MOD271: ACCELERATION ZONE OF UNIDIRECTIONAL CO-FLOWING DIFFUSER

In this laterally contracting zone the diffuser plume becomes VERTICALLY FULLY
MIXED over the entire layer depth (HS = 8.69m).
Full mixing is achieved after a plume distance of about five
layer depths from the diffuser.

Profile definitions:
BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
.00	.00	8.69	1.0	.100E+03	8.69	13.70
.69	.00	8.69	54.0	.185E+01	8.69	13.35
1.37	.00	8.69	54.0	.185E+01	8.69	13.05
2.06	.00	8.69	54.0	.185E+01	8.69	12.79
2.74	.00	8.69	54.0	.185E+01	8.69	12.56
3.42	.00	8.69	54.0	.185E+01	8.69	12.36
4.11	.00	8.69	54.0	.185E+01	8.69	12.18
4.80	.00	8.69	54.0	.185E+01	8.69	12.03
5.48	.00	8.69	54.0	.185E+01	8.69	11.89
6.16	.00	8.69	54.0	.185E+01	8.69	11.76
6.85	.00	8.69	54.0	.185E+01	8.69	11.65

7.53	.00	8.69	54.0	.185E+01	8.69	11.55
8.22	.00	8.69	54.0	.185E+01	8.69	11.47
8.91	.00	8.69	54.0	.185E+01	8.69	11.39
9.59	.00	8.69	54.0	.185E+01	8.69	11.33
10.28	.00	8.69	54.0	.185E+01	8.69	11.29
10.96	.00	8.69	54.0	.185E+01	8.69	11.25
11.65	.00	8.69	54.0	.185E+01	8.69	11.22
12.33	.00	8.69	54.0	.185E+01	8.69	11.21
13.02	.00	8.69	54.0	.185E+01	8.69	11.20
13.70	.00	8.69	54.0	.185E+01	8.69	11.19

Cumulative travel time = 87. sec

END OF MOD271: ACCELERATION ZONE OF UNIDIRECTIONAL CO-FLOWING DIFFUSER

BEGIN MOD251: DIFFUSER PLUME IN CO-FLOW

Phase 1: Vertically mixed, Phase 2: Re-stratified

Phase 2: The flow has RESTRATIFIED at the beginning of this zone.

This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

END OF MOD251: DIFFUSER PLUME IN CO-FLOW

** End of NEAR-FIELD REGION (NFR) **

The initial plume WIDTH values in the next far-field module will be CORRECTED by a factor 1.58 to conserve the mass flux in the far-field!
The correction factor is quite large because of the small ambient velocity
relative to the strong mixing characteristics of the discharge!
This indicates localized RECIRCULATION REGIONS and internal hydraulic JUMPS.

BEGIN MOD241: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.70	.00	8.69	54.0	.185E+01	8.69	17.68	8.69	.00
63.02	.00	8.69	66.3	.151E+01	4.75	39.68	8.69	3.94
112.33	.00	8.69	72.8	.137E+01	3.66	56.55	8.69	5.03
161.65	.00	8.69	77.8	.129E+01	3.11	71.15	8.69	5.58
210.96	.00	8.69	82.2	.122E+01	2.77	84.34	8.69	5.92
260.27	.00	8.69	86.4	.116E+01	2.55	96.54	8.69	6.14
309.59	.00	8.69	90.6	.110E+01	2.39	107.98	8.69	6.30
358.90	.00	8.69	94.9	.105E+01	2.27	118.82	8.69	6.42
408.22	.00	8.69	99.5	.101E+01	2.19	129.17	8.69	6.50
457.54	.00	8.69	104.3	.959E+00	2.13	139.09	8.69	6.56
506.85	.00	8.69	109.4	.914E+00	2.09	148.66	8.69	6.60
556.16	.00	8.69	115.0	.870E+00	2.07	157.91	8.69	6.62
605.48	.00	8.69	120.9	.827E+00	2.06	166.88	8.69	6.63
654.79	.00	8.69	127.2	.786E+00	2.06	175.61	8.69	6.63
704.11	.00	8.69	134.0	.746E+00	2.07	184.11	8.69	6.62
753.42	.00	8.69	141.3	.708E+00	2.09	192.42	8.69	6.60
802.74	.00	8.69	149.1	.671E+00	2.11	200.53	8.69	6.58
852.05	.00	8.69	157.3	.636E+00	2.15	208.49	8.69	6.54
901.37	.00	8.69	166.1	.602E+00	2.19	216.29	8.69	6.50
950.68	.00	8.69	175.5	.570E+00	2.23	223.94	8.69	6.46
1000.00	.00	8.69	185.4	.539E+00	2.28	231.47	8.69	6.41

Cumulative travel time = 9950. sec

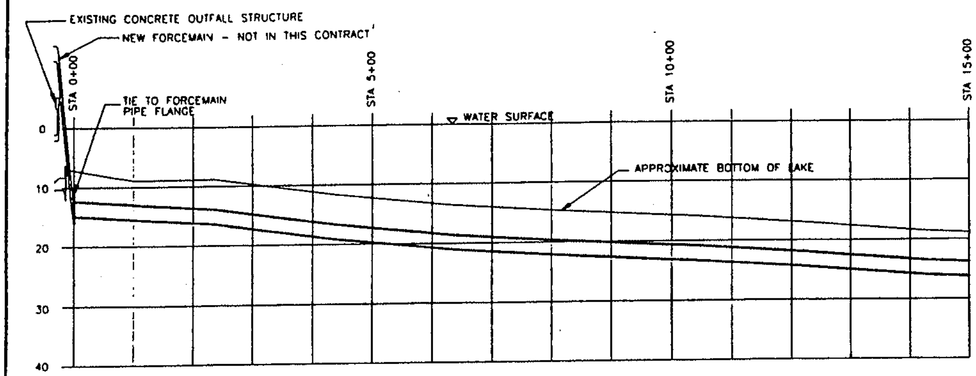
Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD241: BUOYANT AMBIENT SPREADING

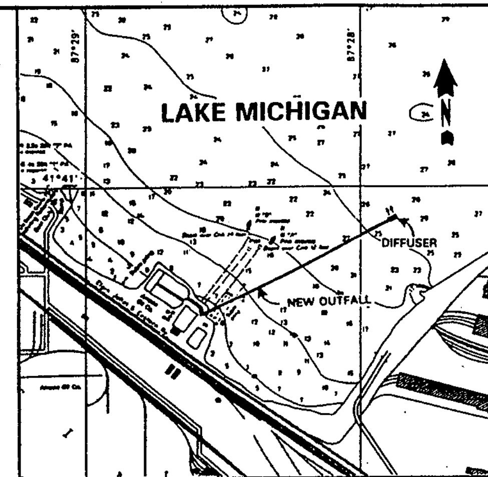
CORMIX2: Submerged Multiport Diffuser Discharges End of Prediction File

ATTACHMENT 3

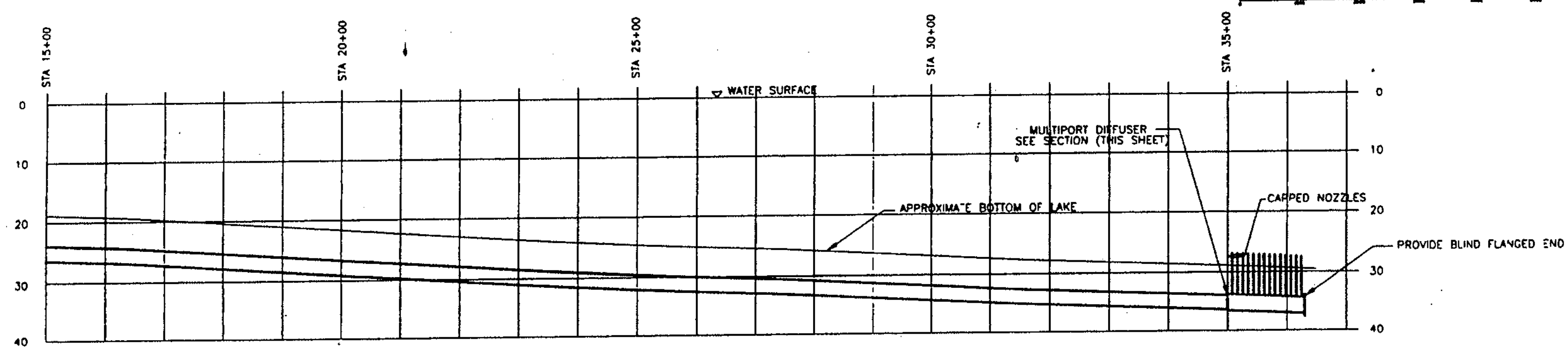
PRELIMINARY DIFFUSER DESIGN



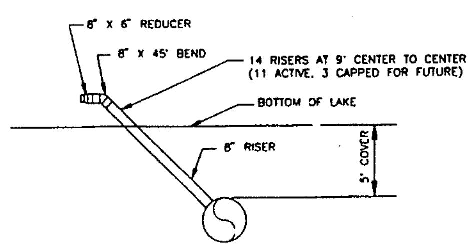
OUTFALL PROFILE
SCALE. 1" = 200' HORIZ
1" = 20' VERT.



SITE LOCATION PLAN
OUTFALL AND DIFFUSER
FEET



OUTFALL PROFILE
SCALE. 1" = 200' HORIZ
1" = 20' VERT.



MULTIPORT DIFFUSER CROSS SECTION
N.T.S

NO	DATE	BY	REVISION

ISSUED	BY	DATE	PROJ	APPN

NOTES

DWG NO.	REFERENCE DRAWINGS

PRELIMINARY

PROJ NO 64527 | APPN NO.

Amoco Oil Company
ENGINEERING DEPARTMENT CHICAGO ILL.

OUTFALL PLAN, PROFILE AND DIFFUSER

THE ADVENT GROUP, INC.

BY UTILITY		LOCATION WHITING	
DATE 8-1-94	SCALE NOTED	SHEET 1	OF 1
ENGRD.	CHKD SCR	DRAWN MLT	APPVD SCR

DWG.D-7121-SK2 | P3

PLOT DATE 8-12-94

?-627\PF-02

ATTACHMENT 4

SOUTH END OF LAKE MICHIGAN

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